A COMPARATIVE STUDY OF VORTICELLA SP. AND HYDRA AT VARIOUS DEPTHS IN A FRESH WATER LAKE

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INTRODUCTION AND REVIEW OF THE LITERATURE

A study of populations has led investigators to find groups of organisms that interact or fluctuate with the seasons. Among the studies, the biologists hope to find organisms which are captive or readily accessible. The aquatic biologists have attempted to show these fluctuations.

A statement by Libbie Hyman in Edmunson (1959) indicated that hydra will be obtained in any unpolluted lake or pond by bringing in the submerged vegetation. Bushbaum (1966) related to the fact that hydra abound in unpolluted streams, ponds or the shore waters of lakes. This leads to the corollary that, as a lake becomes polluted, you could have an indicator organism such as hydra since it has few natural enemies to limit its dispersal. Evidence should then be gathered as to their seasonal distribution.

Welch and Loomis (1924), in their study of _Hydra oligactis_, presented the idea that hydra may thrive in lakes, at depths greater than 10 meters, in seasons during which the temperature approaches within a few degrees of the freezing point. They emphasized the importance of temperature in the disappearance of hydra from the upper regions of a lake, and that hydra migrated downward when the food supply was limited to become muck feeders.

Miller (1936) introduced other factors into the distribution of hydra by relating their population to light, pressure and food. He found food to be of greater importance to their fluctuations in population than the temperature or the season of the year.

Many other investigators found problems in studying the variations. However, Bryden (1952) in his review of the literature proposed that these efforts by earlier investigators were ineffectual in determining a specific reason for the fluctuations in population of the hydra. Since then, the observers have again approached the idea of the ecology of the hydra as a fundamental problem. This was proposed in light of Pennak's (1953) work in Colorado lakes. He continued this work and found the greatest populations occurring in the late spring and early summer followed by a marked decrease in July and August. He generalized by stating that there is a possibility of a bloom in September or October and another in midwinter. In other words, the populations tended to follow some pattern which was discernable. Pennak's (1953) work proved that hydra are absent if the oxygen supply is below a certain minimum. No attempt seems to have been made to determine population levels at depths below 16 meters. Since the oxygen supply is known to be a limiting factor, these observers have not attempted a population study below the thermocline.

Bryden's (1952) work, because of the nature of the lake, did not enable him to sample the population of hydra at depths. He, however, did find a fluctuation in the populations. Again, as Pennak (1953) determined, the peaks were similar during the summer and early fall; but a population moved from the vegetation that was present during the summer to other places but, again, not in the numbers present as before. The population rose in January, but then declined until May, when it again began to rise.

The ideas put forth by these authors give us a general background into the nature of the fluctuations, growth and problems concerning a population of hydra. Specific species of hydra were always studied and proved to be good indicators of the nature of the lake.

There has been a considerable amount of work done on the next group of organisms, the vorticellids. Manwell (1961) pointed out that the work was begun by Leeuwenhoek who first observed vorticellids and published his observations. He referred to the vorticella as a "poor little creature" and stated, "when striving to disentangle (its) tayle (its) whole body lept back towards the global of the tayle, which rolled together serpentlike." Since then these sessile organisms have been the subject of many intensive studies. Among the researchers of these populations was Noland (1925) who observed their ability to detach themselves and swim about if adverse conditions were present.

Hyman (1940) mentioned that ciliates are sensitive to heat, chemicals and contact but are indifferent to light. The latter factor would indicate that if pressure was not a factor, these organisms could be found equally distributed throughout an area of study.

Eggleton's (1931) study showed that the maximum population present in the deepest portion of the lake occurred around late fall. The decline from this peak would start in early spring, be continuous until midsummer and then show a slight increase. However, Eggleton (1931) could not find a uniform distribution from deep to shallow waters.

Much of the work today is being done at the Stammer School in Errlangen. Among the observers, Sladacek (1958) proposes that if oxygen is present to enable aerobic conditions, the presence of <u>Vorticella</u> <u>microstoma</u> is an indicator. Stiller (1960) maintains that the presence of protozoa is dependent upon physiochemical rather than geographical characters. Noland, in Chen (1967), has proposed that <u>Vorticella</u> have a wide range of tolerance for certain conditions. He concluded (that) "the nature and amount of available food was more relative to their abundance and distribution than other factors." This leads to Manwell's (1961) remark that "temperature may in turn determine the abundance of food."

Kudo's (1963) idea was that <u>Vorticella</u> were oligosaprobic forms since they inhabit water which is rich in mineral matter, but in which no purification processes are taking place. The understanding of this remark is incongruous with Noland's and Gojdic's conclusion in Chen (1967). They stated that Vorticella are a continuous member of sewage fauna with some seasonal variation in population. It should therefore, be noted that Vorticella can withstand some adversity. If conditions become extreme, they can swim off.

Webb's (1961) conclusion is (that there is) "much confusion in the literature concerning the distribution of protozoa in relation to anoxia." She had found Vorticella sp. at depths of 3, 5, 8 and 10 meters, but none at 12 or 15 meters and mentioned no quantitative data. Therefore, she put vorticellids into a group which occur in very small numbers and as scattered individuals where there is little bacterial decomposition and the water is well oxygenated. As conditions change from the presence to an absence of a thermocline which would be a limiting factor for the oxygen content, their numbers would decrease with the absence of oxygen and would become uniformly distributed with the presence of oxygen throughout. But, even with the presence of oxygen, there were none found at depths greater than 10 meters.

The relationship becomes more confusing when Imal (1915) found Vorticella sp. in anaerobic mud at the bottom of Center Lake, Indiana. Here there were conditions of growth previously unobserved. Involving conditions other than chemical, Zimmerman, in Chen (1967), observed that Vorticella sp. could survive most speeds of current but grew best in water flowing at 15-25 cm. per sec. This could explain the absence of vorticellids by other observers at any depths. The reason apparently was not chemical but due to the slower movement of the water. The necessity of taking water currents in population studies may be necessary. Indeed, the currents may be the most integral part of a study.

Yet, with all things taken into consideration, it must be concluded that, to be accurate, a population study should be done in the natural environment and for a long period of time. Then a statement of fluctuations can be validated. The methodology used in the past still presents the same problems. The difference of a few centimeters in the area of sampling could present varying conclusions. Reliable data must be obtained via the best methods; once established, they must be followed throughout a study.

Welch and Loomis' (1924) methods of removing the hydra from the materials present led to consistant data. The same methods were used by Miller (1936) in his studies. These were good but lacked the definition of the area studied. In both cases the plants were removed and immersed in a container before the organisms were removed and counted. The effects of depth were studied alike by placing organisms gathered from a given depth to a greater one. Both observers found that the organisms did not survive the change in depth. This might have been due to constant manipulation to which the hydra is sensitive, to the change in depth which hydra proved they could not tolerate, or to the results of the depth.

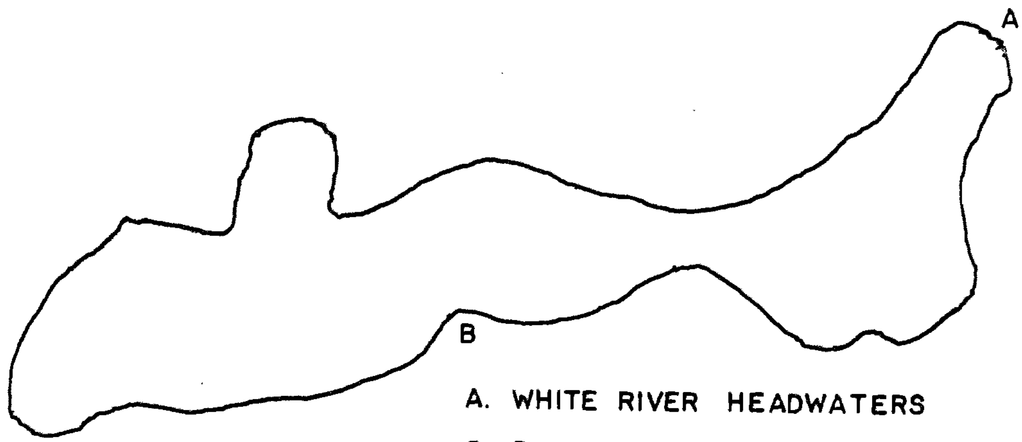
Bryden's (1952) work was done mainly with glass plates and he questioned the selectivity of these plates by the hydra as a true quantitative sample. Since then, many variations of the glass slide have been used in sampling sessile forms.

Hydra sp. from the freshwater coelenterates and Vorticella sp. from the sessile protozoa have been found in most freshwater lakes, ponds and streams. Their numbers in respect to depth and time are the subject of this paper. Hydra sp. and Vorticella sp. most generally are bethos occupying organisms attached to various substrata such as rocks, twigs or leaves. It is difficult to count these organisms with accuracy when bringing up samples attached to substrata from a depth. Various methods have been used to substantiate the occupancy of these organisms, but none have been successful at depths greater than 12 meters. The assumption has been made that they occur at greater depths, but a seasonal record has never been obtained. Thus, the purpose of this study was to determine the populations over a period of one year at depths of 2, 5, 10, 20 and 30 meters in a Wisconsin lake.

METHODS AND MATERIALS

The study was made on a fresh water lake in southern Wisconsin, Lake Geneva. Martin (1916) points out that the lake lies in a belt of strong terminal morraine. The pre-glacial valley of the area is buried beneath 220 feet of glacial drift. Hills around the lake rise 100-200 feet above the water surface. The lake was formed by the Delavan Lobe of the Wisconsin glacier blocking the western end of the river channel according to Jenkins (1922). He also explains that a finger of the glacial lake remained in the channel of the present Lake Geneva preventing the laying down of drift. This lake is classified as an oligotrophic lake covering an area of 5262.4 acres. The Wisconsin Conservation Department (1967) has measured the lake's mean depth at 61 feet; maximum depth is 135 feet with 1 per cent of it under 3 feet and 77 per cent of it over 20 feet in depth. The total volume of the lake is 320,984 acre feet. It is mainly spring fed with only two small streams running into it which are of little consequence according to Fenneman (1910). It has 20.2 miles of shoreline and an elevation of 861 feet above sea level. Figure 1 is a map of the lake.

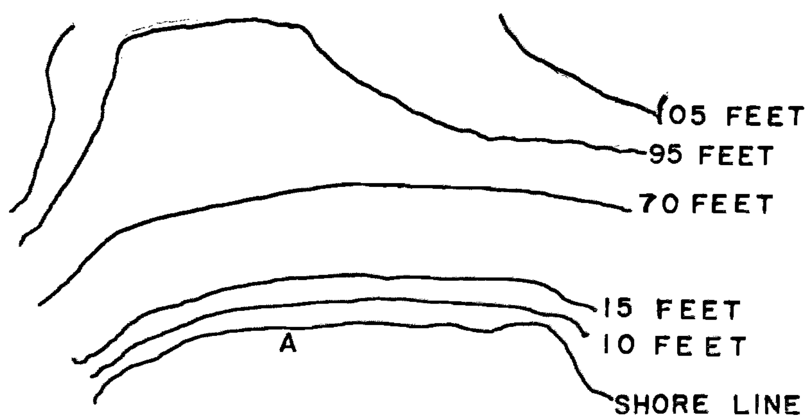
The area of the lake chosen for study is located in section eight of Walworth County of the State of Wisconsin. It is referred to as Black Point. The reason for choosing this part of the lake to study is that the depths desired



A. WHITE RIVER HEADWATERS

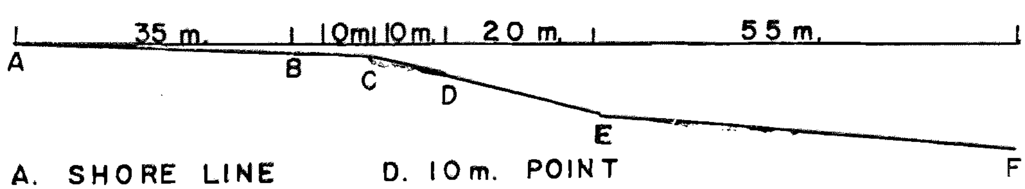
B. BLACK POINT

FIGURE 1 GENEVA LAKE, WISCONSIN



A. POINT DUE NORTH FROM WHICH SURVEY WAS MADE.

FIGURE 2 BLACK POINT.



A. SHORE LINE
B. 2 m. POINT
C. 5 m. POINT
D. 10 m. POINT
E. 20m. POINT
F. 30m. POINT

FIGURE 3 PROFILE OF PROJECT. SHOWING DISTANCE FROM SHORE.

can be reached within a reasonable distance from shore. Figure 1 shows the location of the point to be such that it will be affected by the materials that enter the lake from the western shoreline. The currents run from west to east with the only outlet located in the northeast corner. This is where it forms the White River of the Fox River drainage.

The methods of collection were those established by Burbank and Allen (1947) with modifications.

Determining the distance from shore for the desired depths was done with a fishline held by a person on the shoreline and another in the boat. Hence, by rowing out and determining the depths, the distances were measured in meters on the aforementioned fishline which had previously been marked in meters. The depths were found by using sonar equipment reinforced by a dropline. As shown in Figures 2 and 3, a profile of the lake bottom due north from a point on shore was obtained. With this data a wire line was anchored and strung from shore; slide boxes were placed at the desired distances according to the bottom profile. Weights of bricks were placed between the boxes with the end weight placed 50 cm. from the box. This spacing was used after divers found muck to be 25-40 cm. in depth. It was designed to prevent burial of the boxes and, upon reconnaisance by the divers, proved effective.

The boxes were constructed to hold three standard glass microscope slides 2.5 cm. apart. They were wooden and open both top and bottom. Holes were drilled in the end; wire was looped through both ends. When the slides were placed in slots which had been sawed into the sides, the wire was looped around to hold the slides in place.

Attempts were made to recover the slides every two weeks because, upon observation of several recovered boxes of slides, it seemed that the maximum population attached itself in two weeks.

Hydra and vorticellids were chosen for study because they are normally sessile but have the ability to move. Noland (1925) found that the vorticellids can detach themselves and move. Lentz (1966) points out that hydra have the ability to move into or out of an area by either forming a bubble to float out on or by a slower form of movement such as tumbling.

Countings of the vorticellids and hydra were made in the laboratory. The slides were recovered from the boxes and placed in separate jars. Slides that had been cleaned in the laboratory were used to replace the slides removed. During the first phase of the project the slides were first counted on the shoreline and immediately placed back at the desired depths, without cleaning, parallel to a separate apparatus with clean slides. It was noted that there were more hydra attached to the new slides. With this background it was decided to use clean slides at all times.

The slides taken to the laboratory were first observed with a stereomicroscope to determine the number of hydra on both sides of the slide. If hydra had detached during transport, they were found in the jar and included in the count. Data was thus recorded.

The vorticellids were counted by placing a 22 x 22 mm glass coverslip directly in the center of the slide and observing the slide with a standard laboratory compound Graf Apsco model GK 3 microscope having a mechanical stage and a Bausch and Lomb Optilume Lamp. This microscope was used throughout the study. Counting was done with a 10x objective using a 10x ocular and identification with a 44x objective using a 10x ocular. The count was made by moving the slide with the mechanical stage micrometer, according to the diameter of the field, enough to view the entire coverslip. The count was made for each slide and an average of the three slides was used as a sample of the population. This information was thus recorded.

Surface temperatures were recorded on each retrieval. Temperatures and oxygen levels in parts per million were taken on October 14, 1967, and on July 30, 1968.

It was found by Gilbert (1965) that there was no significant difference in numbers of organisms regardless of the side of the slide which was counted. However, in contrast, the apparatus used in this study was always placed flat so that the slides were vertical.

The data on the thermocline normally seen in Lake Geneva was obtained from the State of Wisconsin Natural Resources.

DATA AND DISCUSSION

The presence or absence of natural support for a sessile organism is of great concern in dealing with quantitative data in determining the populations of these organisms. The data can be used as an indicator of absence or presence of populations. It should not be disregarded completely that the organism will prefer natural support in contrast to a glass slide because of the likelihood that there will be more food available on or near a natural support. Therefore quantitative data, specific to the numbers of hydra that would normally be occupying a definite area, has not been utilized. This should be considered when enough proof becomes available as to the ratio between the actual and the observed populations. It is possible to explore the fluctuations from the available data with regard to emphasis on the original problems.

The problem was first started in August of 1967 with the introduction of slide holders at various depths. These were first attached to floats allowing the researcher to recover the slides at ease. Other people utilizing the lake could also recover these at ease, so this method was abandoned. Two alternatives were probed; one, using a 130 pound test fishline for attachment to shore and at various intervals of depth, proved inadequate. The line broke after a continuous pounding of waves and currents caused the line to entangle with weeds. Fishermen and skindivers also removed the materials from the correct position. This practice proved so detrimental that, as a last resort, a wire was attached to shore. Approximately one-third of the data obtained was not used because the apparatus had been damaged either by natural causes such as waves, ice, weeds or by human curiosity. The latter proved most prevalent. This data is not included within the tables. Other data not included is that involving the different time periods. When first attempting to ascertain the amount of time that the apparatus should be left down, several lines were placed at depths studied and were checked at intervals of one, two, three and four weeks. Each time they were returned to the water and checked at the next time period.

Population determinations were made by first removing the slides from one test line that had been down one week, counting the organisms and replacing the line. After one more week, the one week and two week lines were removed, organisms counted and line replaced. After an additional week the one week and three week lines were removed, organisms counted and the one week line was replaced. Continuing one more week, the one, two and four week lines were removed and the organisms counted. It was determined from this data that the two week timing yielded the best data, since slides immersed for two weeks showed double the number of organisms as the one week slides; the three and four week slides showed no appreciable increase in number of organisms. It was evident that the space available was filled by the organisms in the two week period.

The need for the use of clean slides was determined by placing two lines at the same intervals. Upon retrieving the slides of both lines after two weeks and counting the organisms, one line was replaced with clean slides, the other used the same slides that it previously had. Removing the slides again in two weeks revealed that the cleaned slides had more organisms attached than the old slides. Exploration of this phenomena should be pursued. It could be algal growth or deposits on the slides inhibiting the attachment of sessile organisms which caused this phenomena.

Another determining factor as to the presence or absence of free oxygen was attempted at two time periods. The method of determination was the use of a Kemmerer Sampler and a quick oxygen determiner. This data indicated a lack of normally sufficient oxygen. With these thoughts in mind, you can follow the general procedure of how these groups of populations interacted.

The numbers of Vorticella sp. as shown in Figure 4 at 2 meters varied according to the seasons. This can be noted, that during the time that the water temperature was low, the population was at its lowest point. This is evidenced by the extremely low population from November through March. However, the population also declined when the water temperature was high, indicating that their maximum tolerability was approached. Since these organisms can migrate, it is evidenced by this fluctuation. This can be interpreted by the maximum population of 248, 505 and 500 during May and June, but falling off during August. The remarkable similarity between Vorticella sp. and hydra is probably due to the same reason.

In Figure 5, there is a high peak in the population in November of 1967, followed by a low ebb of zero to two organisms from December through May. In June and July the number of hydra present average nine, with a decline in August and September, then increasing again in October. The decrease in August could be due to the fact that the maximum in temperature tolerance was reached and the organisms migrated from the area.

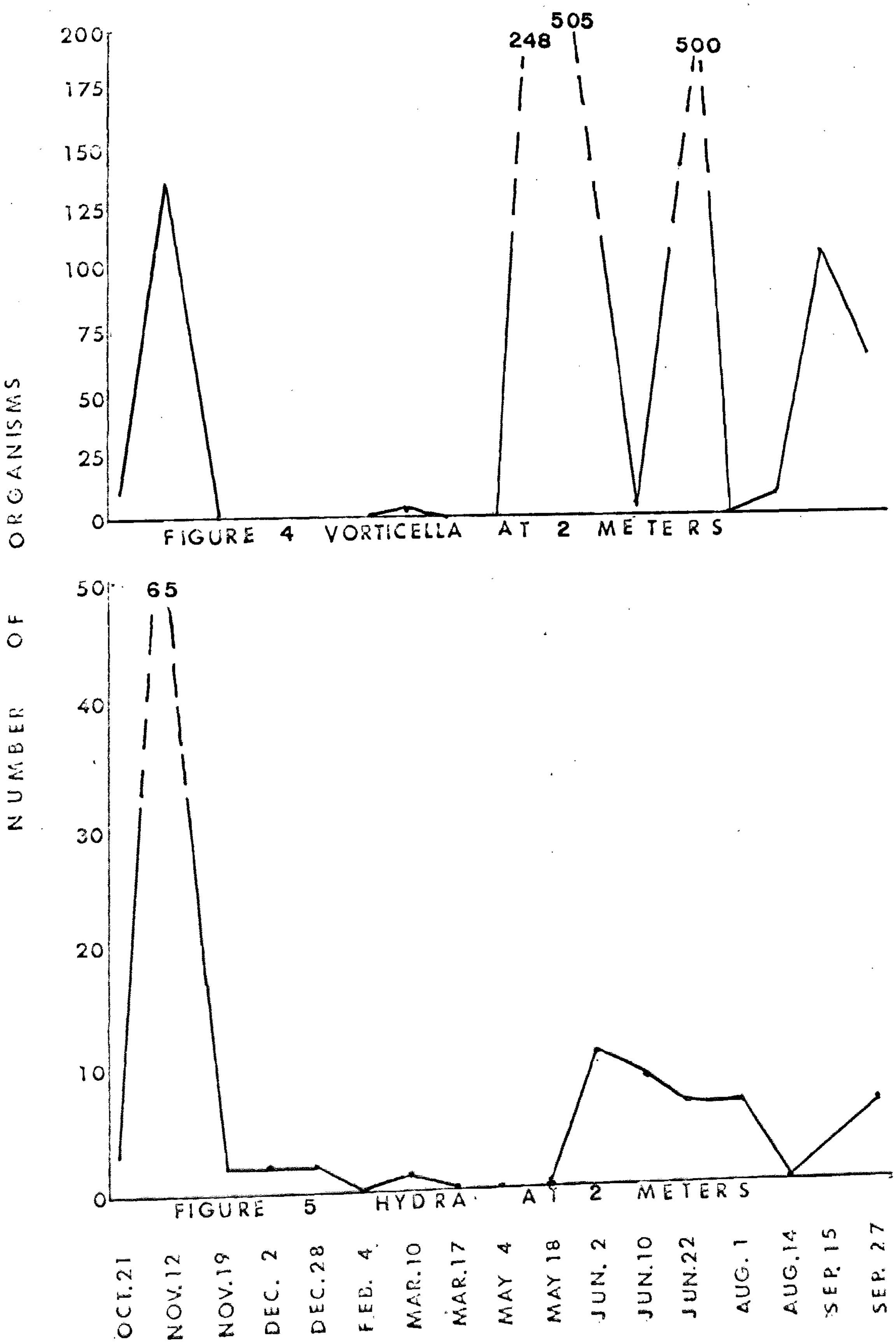

NUMBER OF ORGANISMS
200
175
150
125
100
75
50
25
0
248
505
500
FIGURE 4 VORTICELLA AT 2 METERS
50
65
40
30
20
10
0
FIGURE 5 HYDRA AT 2 METERS
OCT.21
NOV.12
NOV.19
DEC. 2
DEC.28
FEB. 4
MAR.10
MAR.17
MAY 4
MAY 18
JUN. 2
JUN.10
JUN.22
AUG. 1
AUG.14
SEP. 15
SEP. 27

Figure 6 shows the vorticellid population at 5 meters following similar fluctuations as at 2 meters except for lower peaks in May and June. In Figure 7, the hydra population at 5 meters is shown to be similar to that at 2 meters in fluctuation except for higher peaks in May and June.

The comparison of Figures 8 and 9 indicates that the two populations are interacting. The populations of vorticellids increase in the area before those of hydra do. This would indicate that conditions become favorable earlier in the year for the vorticellids than for the hydra. The interaction suggests that the vorticellids can migrate faster than the hydra or that the reproductive rate enables the vorticellid population to reveal itself earlier.

Figure 10 indicates that there is a fairly stable population of vorticellids throughout the year. In contrast, Figure 11 indicates that the population of hydra migrates to the deeper water during the freeze over, migrate out, then return in May before the thermocline sets up, only to decline in numbers at this point.

The numbers of vorticellids are definitely few at thirty meters but the evidence that a large population exists during freeze over, as shown in Figure 12, gives an indication of their migratory urge to move to the area where a minimum of their tolerable habitat will be found.

This migratory urge to move is demonstrated also by the hydra as graphed in Figure 13. However another problem

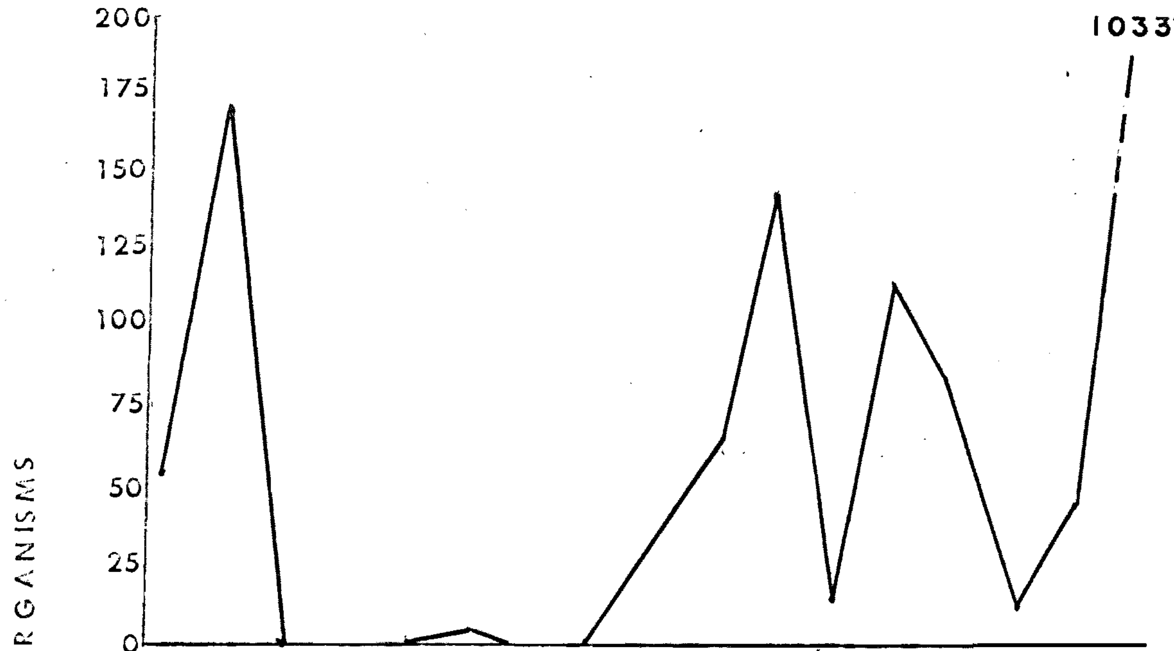


FIGURE 6 VORTICELLA AT 5 METERS

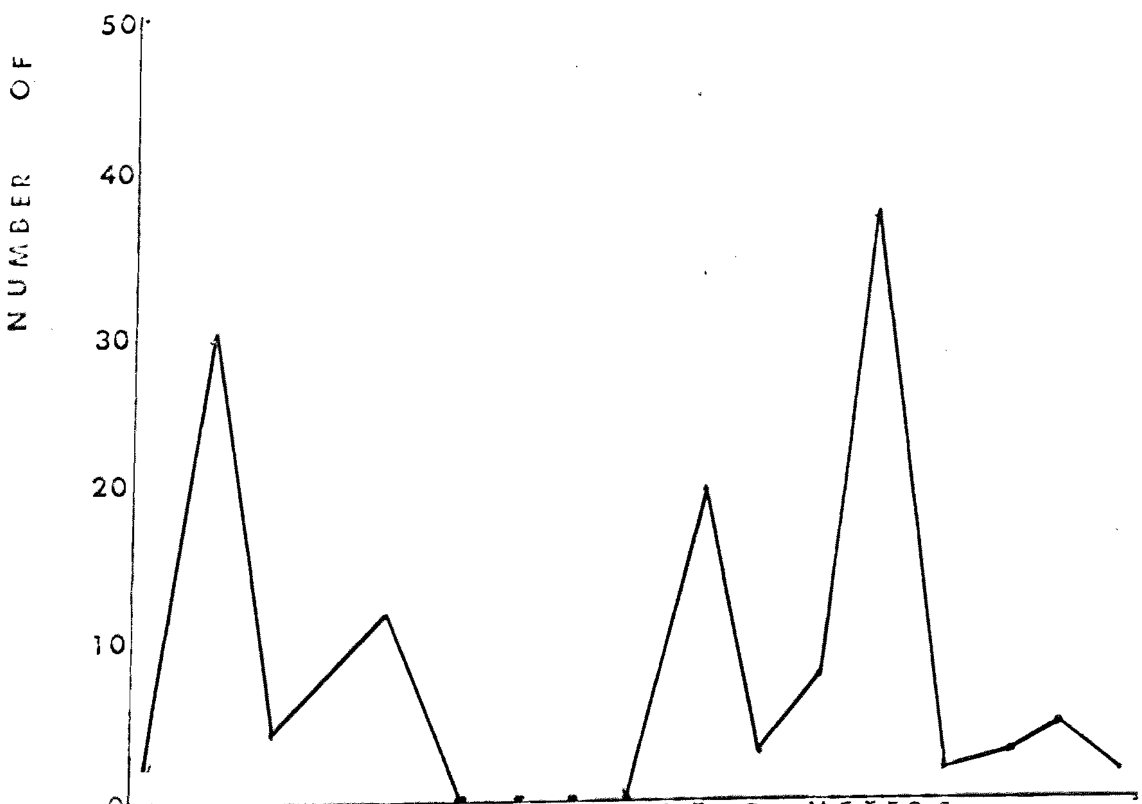
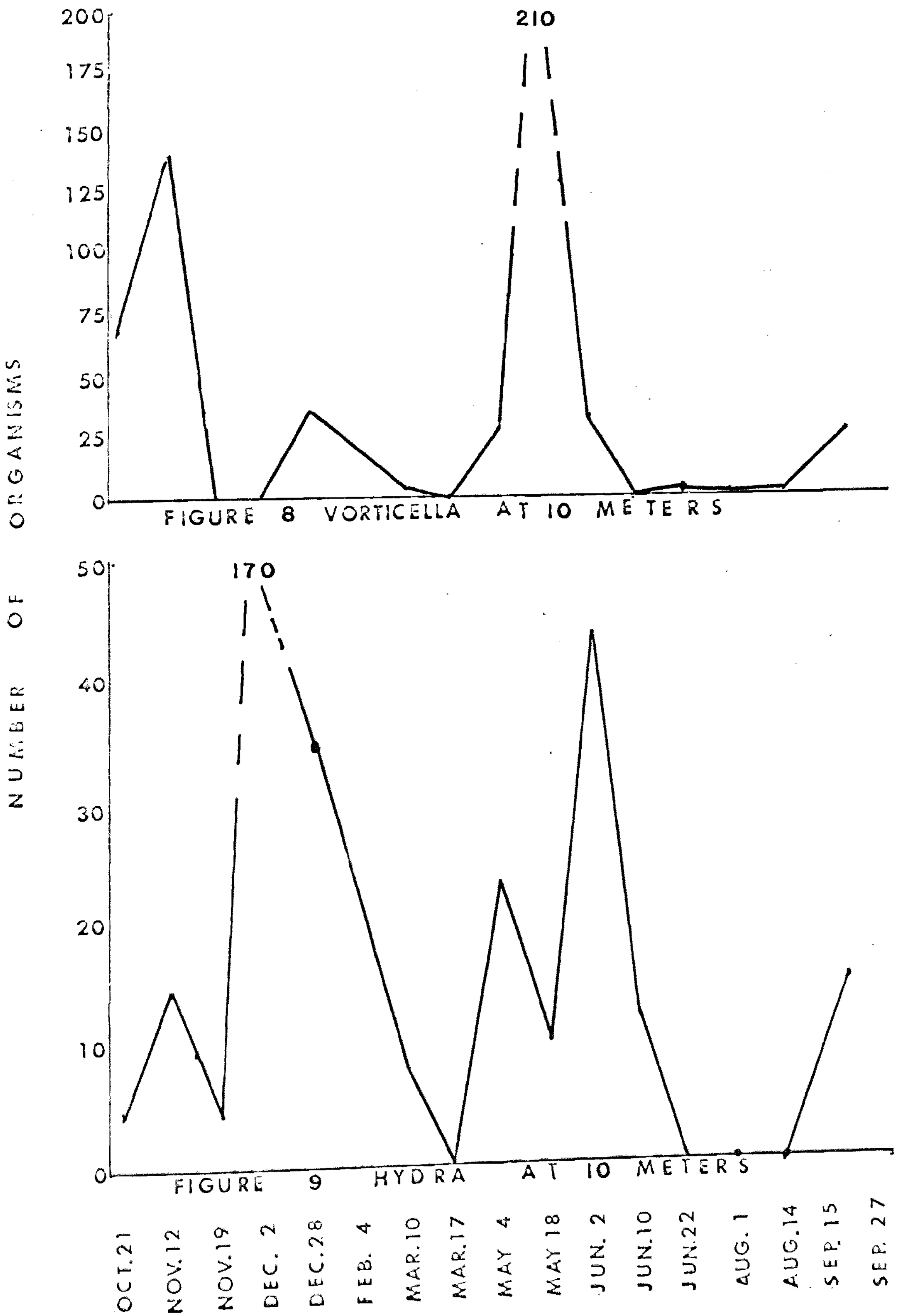


FIGURE 7 HYDRA AT 5 METERS



210
200
175
150
125
100
75
50
25
0
FIGURE 8 VORTICELLA AT 10 METERS
NUMBER OF ORGANISMS
170
50
40
30
20
10
0
FIGURE 9 HYDRA AT 10 METERS
OCT.21
NOV.12
NOV.19
DEC. 2
DEC.28
FEB. 4
MAR.10
MAR.17
MAY 4
MAY 18
JUN. 2
JUN.10
JUN.22
AUG. 1
AUG.14
SEP. 15
SEP. 27

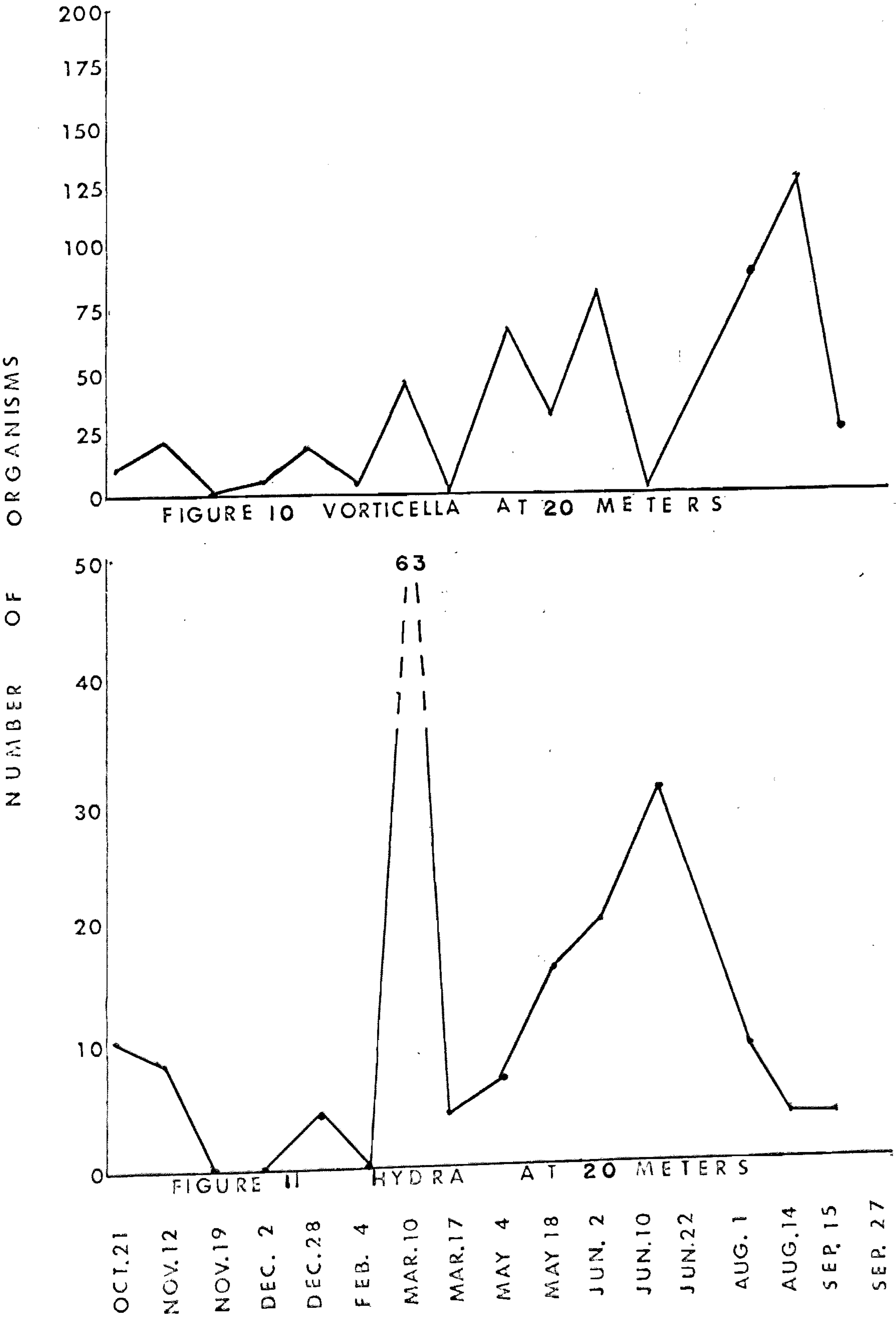


FIGURE 10 VORTICELLA AT 20 METERS

FIGURE 11 HYDRA AT 20 METERS

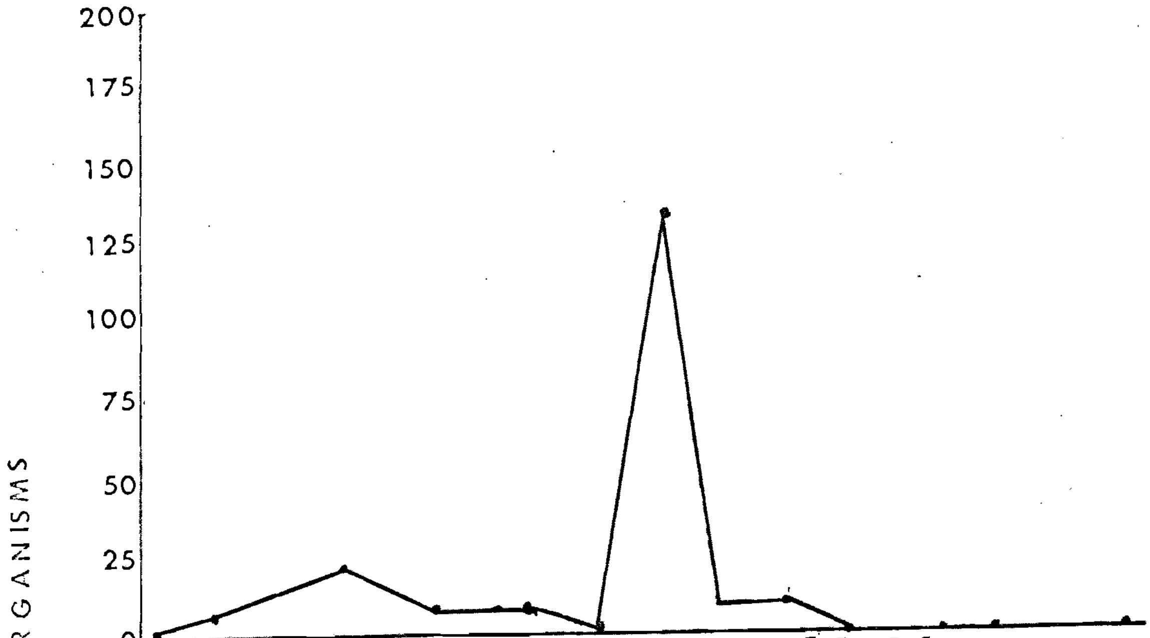


FIGURE 12 VORTICELLA AT 30 METERS

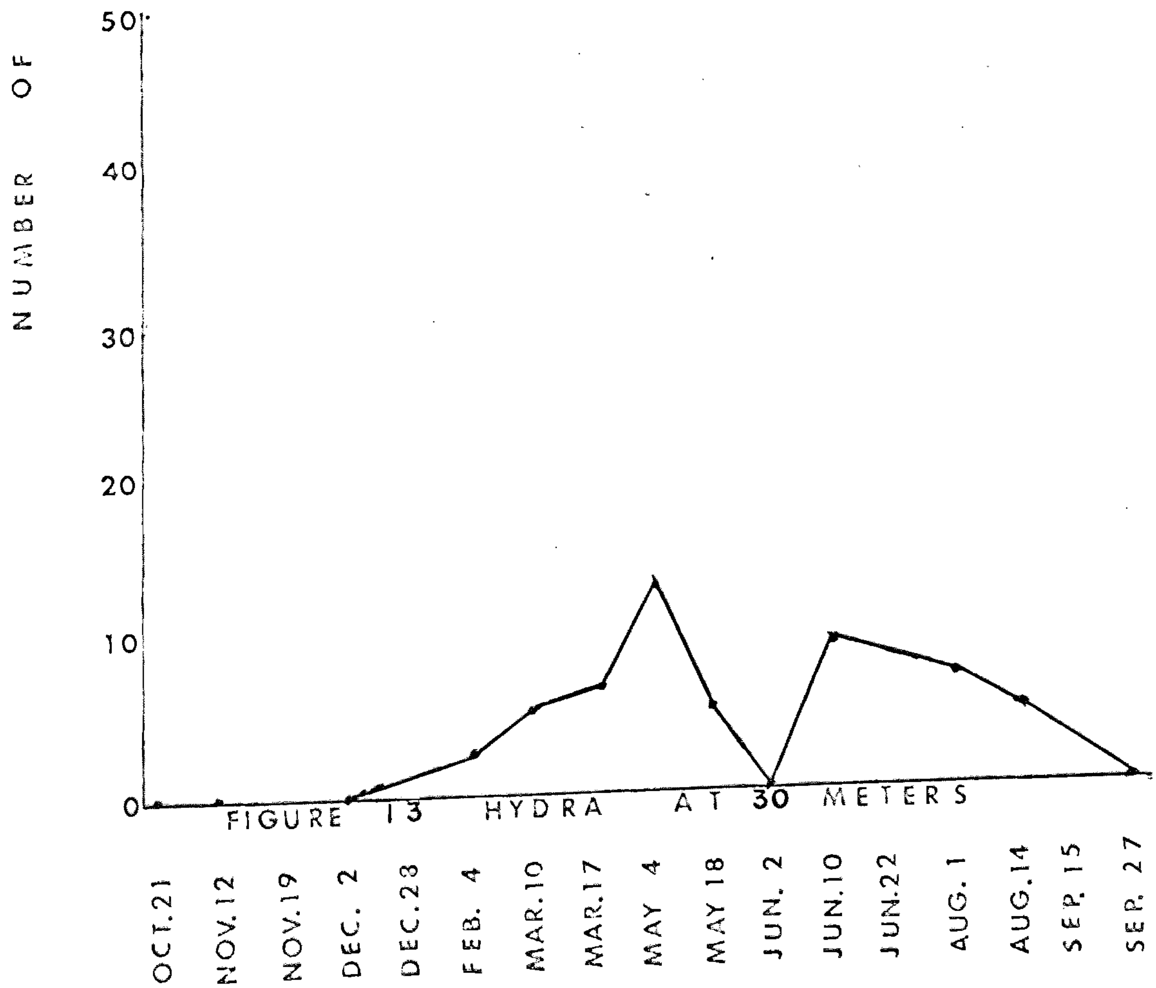


FIGURE 13 HYDRA AT 30 METERS

is presented in finding hydra at this depth even though a seasonal thermocline has been established. This is indicative of a low amount of dissolved oxygen.

The comparison of the overall populations, shown in Figures 14 and 15, indicates that the population is present at all times with peaks for the vorticellids in May and June while the hydra population peaks during late fall.

From Table 1 it can be noted that, at 20 and 30 meters, 2 to 3 ppm of dissolved oxygen is available. Comparing this with Figures 11 and 13 for these dates, proves that hydra is surviving under these conditions. However the greater population was always associated with ample concentrations of oxygen. According to the Wisconsin Conservation Commission, the thermocline is normally found between 30 and 35 feet dependent upon the summer month and the time of day. The amount of dissolved oxygen drops considerably during this period but has not reached a level below 0.5 ppm.

Even from the review of the literature, where several authors have stated that the populations are limited by the lack of available oxygen, this study does not bear that out. According to Pennak (1957), this cyclic situation is very short and the majority of protozoan species tolerate the wide range of tolerances. MacArthur and Connell (1966) related that each population is dependent on the activities of others. Any random or cyclic variation in environmental

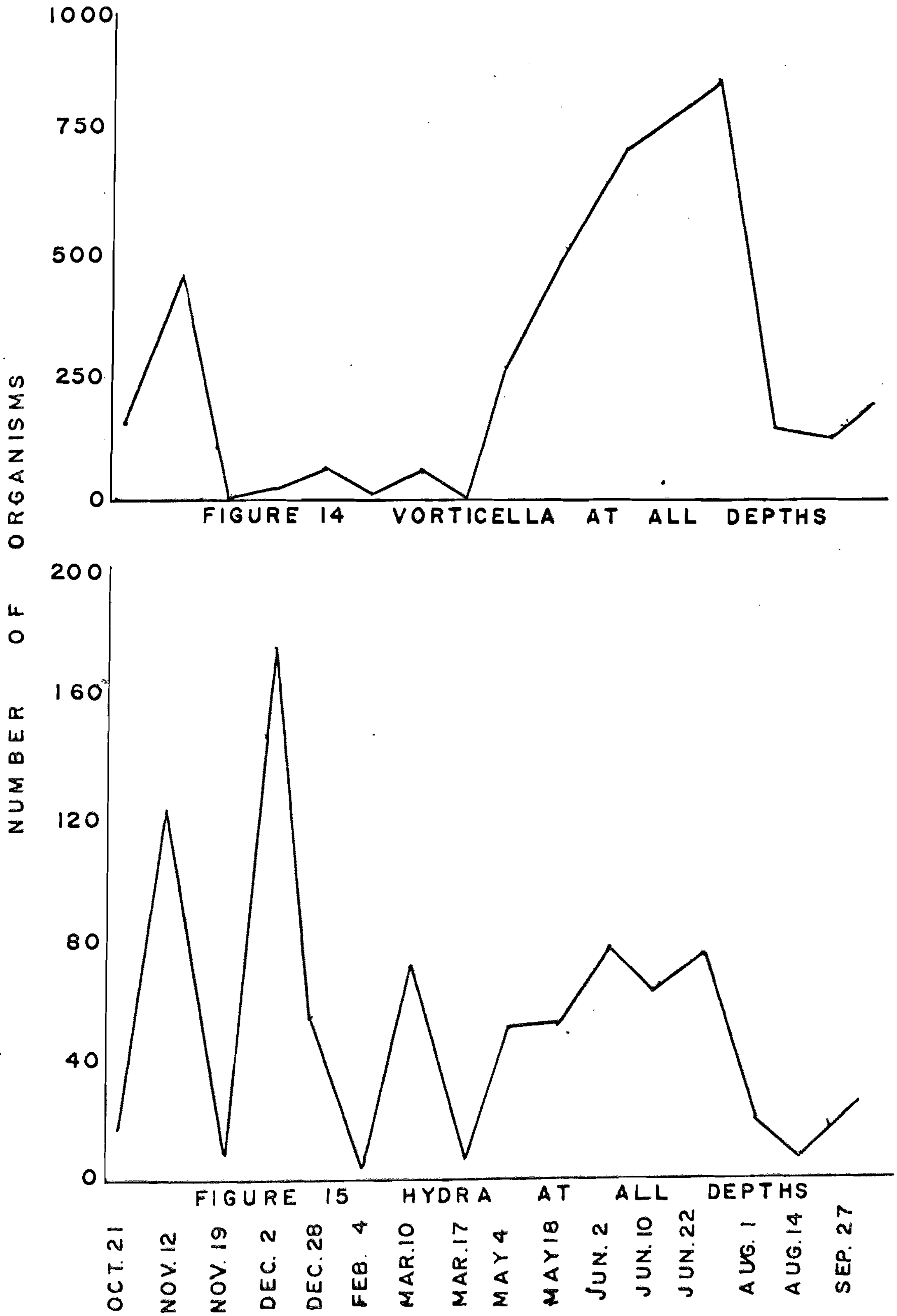


FIGURE 14 VORTICELLA AT ALL DEPTHS

FIGURE 15 HYDRA AT ALL DEPTHS

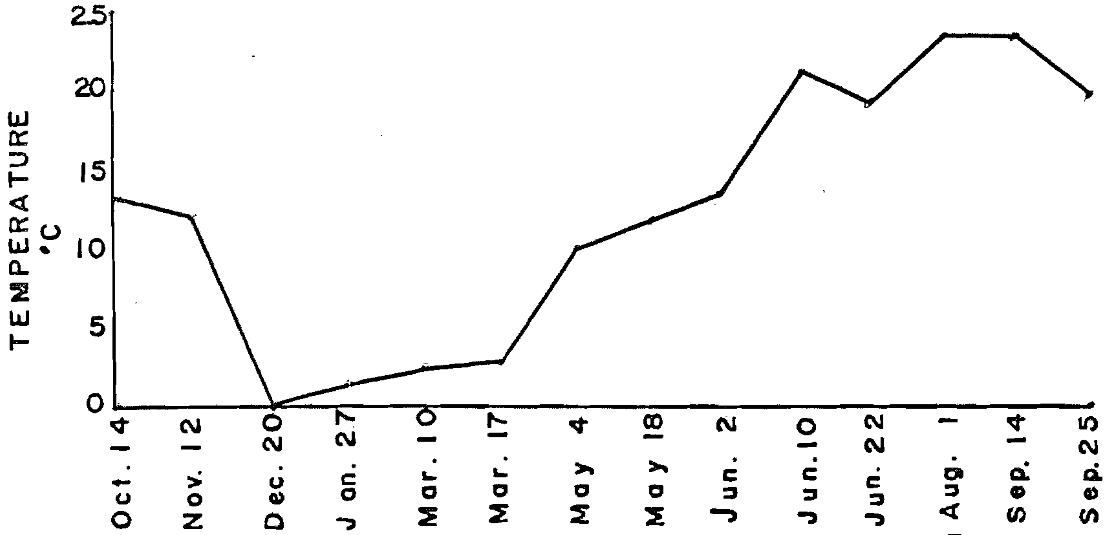


FIGURE 16 SURFACE WATER TEMPERATURE

TABLE I. TEMPERATURE AND DISSOLVED OXYGEN

Depth in meters	Temperature (°C)	Dissolved Oxygen (ppm)
Oct. 14, 1967		
2	20.3	9
5	20.2	
10	20.2	8
20	14.8	
30	9.5	2
July 30, 1968		
2	24	8
5	24	
10	20	
20	10	
30	10	2

conditions is a challenge that the organism must react in order to survive. This survival is pointed out by the presence of hydra and vorticellids at the depths studied.

CONCLUSIONS

A study was made to ascertain that the population of Vorticella sp. and Hydra is maintained at the depths of 2, 5, 10, 20 and 30 meters. This study was conducted on a Wisconsin lake from September of 1967 until September of 1968. The population of these organisms was verified at all of the aforementioned depths. At 2 meters, the population of vorticellids was found to be the highest during May and June. This is the depth of greatest fluctuation in the population for the year as a whole. Whereas at 20 meters, the population is the most stable year around. The population of vorticellids at 30 meters was only present from November until May, but the hydra population was present from February until August.

The peak for the population of vorticellids is in the spring in contrast to the hydra which peaks in the fall. Both populations tend to fall to the lowest ebb in the winter months. There is no depth where the hydra population is stable. It peaks two to three weeks following the peak of the vorticellids at 2 and 10 meters. It is concluded that these populations of sessile organisms fluctuate in size according to the change in seasons. The exact cause or causes of this change has not been ascertained. It is suggested that temperature of the water is a factor in determining the density of populations. However, this factor could influence the availability of food, thus limiting the population to certain areas of the lake. It can be stated that they do migrate, either by accidental currents or movement, to the area which best suits the limits of their tolerance.

The tolerance of hydra to a low concentration of oxygen is not a limiting factor. The presence of these organisms in areas where the amount of dissolved oxygen is extremely low, indicates that in nature, these organisms may migrate to areas where the dissolved oxygen level is supposedly below their minimum tolerance. Thus it can be definitely stated that a migratory population, however unstable, is in existence at all times.

LITERATURE CITED

Bryden, R. R. 1952. Ecology of Pelmatohydra oligactis in Kirkpatrick Lake, Tennessee. Ecological Monograph, Volume 22 (1):45-68.

Burbank, W. D., and J. M. Allen. 1947. A Simple Method of Collecting Small Sessile Fresh Water Forms. Turtox News, XXV (December):241.

Bushbaum, Ralph. 1966. The Lower Animals. Doubleday and Co., Garden City, New York. 303 p.

Chen, Tze-Tuan. 1967. Research in Protozoology. Pergamon Press, New York. Volume II.

Edmondson, W. T. 1959. Fresh Water Biology. John Wiley and Sons, Inc., New York. 1248 p.

Eggleton, Frank E. 1931. Profundal Bottom Fauna. Ecological Monograph 1:231-331.

Fenneman, N. M. 1910. Lakes of Southeastern Wisconsin. Wisc. Geol. Natur. Hist. Surv., Madison, Wisc. 212 p.

Gilbert, S. R. 1965. Seasonal Effects on the Population of Certain Species of Sessile Protozoan Found in the Water of Clear Lake, Iowa. Unpublished Master's thesis, Drake University. 49p.

Hyman, Libbie H. 1940. The Invertebrates: Protozoa through Ctenophora. McGraw Hill Book Co. Inc., New York. Vol. 1.

Imal, H. G. 1915. Some Preliminary Observations on the Oxygenless Region of Center Lake, Kosciusko Co., Indiana. Indiana Acad. Sci. Proc. 345-356.

Jenkins, Paul B. 1922. The Book of Lake Geneva. The Univ. of Chicago Press, Chicago, Ill. 861 p.

Kudo, Richard. 1963. Protozoology. Charles C. Thomas Publ., Springfield, Ill. 1174 p.

Lentz, T. L. 1966. The Cell Biology of Hydra. John Wiley and Sons, Inc., New York. 119 p.

MacArthur, Robert H., and Joseph H. Connell. 1966. The Biology of Populations. John Wiley and Sons, Inc., New York. 200 p.

Manwell, Reginald D. 1961. Introduction to Protozoology. St. Martins Press, New York. 642 p.

Martin, Lawrence. 1916. The Physical Geography of Wisconsin. Wisc. Geogr. Natur. Hist. Surv., Madison, Wisc. 549 p.

Miller, Donald E. 1936. A Limnological Study of *Pelmatohydra* with Special References to their Qualitative Seasonal Distribution. Trans. Amer. Micro. Soc. 55(2): 123-193.

Noland, L. E. 1925. Factors Influencing the Distribution of Freshwater Ciliates. Ecology. VI(October):450.

Pennak, R. W. 1953. Freshwater Invertebrates of the U.S. The Ronald Press Co., New York. 769 p.

Pennak, R. W. 1957. Species Composition of Limnatic Zooplankton Communities. Limnol. Oceanogr. II:126-165.

Sladacek, V. 1958. Die Abhangigkeit des Belebtshlammver Fahrens von physikalischen, chemischen und biologischen Faktoren. [In German, English summary] Verh. internat. Ver. Limnol. 13:611-616.

Stiller, J. 1960. Die limologishches des Naturschutzgebietes von Batorliget in Ungarn nebst Beschreibung einiger neuer Poritrichen-Arten (Ciliata, Protozoa). [In German, English summary] Arch. Hydrobiol. 186-260.

Welch, P. S., and H. A. Loomis. 1924. A limnological Study of Hydra oligactis in Douglas Lake, Michigan. Trans. Amer. Micro. Sco. 43:203-235.

Webb, M. G. 1961. The Effects of Thermal Stratification on the Distribution of Benthic Protozoa in Esthwaite Water. J. Anim. Ecol. 30:137-151.